PANORAMIC MAKER ENGINE FOR A LOW PROFILE SYSTEM

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FIELD OF INVENTION

[0001] This invention relates to software for making a panoramic image on a low profile system.

DESCRIPTION OF RELATED ART

[0002] Digital photography is becoming more popular today as digital cameras and scanners are becoming widely available. Digital images can be created either by capturing a scene using a digital camera or digitizing a traditional film-based photograph using a scanner. One particular advantage of digital photography over traditional film-based photography is that digital images can be easily manipulated or edited for better presentation.

[0003] When a photographer captures a scene using a camera, the desired field of view may be larger than the normal field of view of the camera. Digital photography allows a panoramic image to be produced without the need of purchasing special equipment such as a panoramic camera or a fisheye lens. For example, a photographer with a digital camera may capture a series of digital pictures of a scene by rotating the camera and taking pictures in a sequence of different directions. The captured images may then be projected onto a cylinder and then stitched together to produce a panoramic picture of the scene. Similarly, film-based photographs can be digitized, and the panoramic picture can be composed by projecting and stitching together the digitized images. Presently, digital image programs are available for stitching multiple digital images together to form a panoramic picture. Exemplary programs include Ulead Cool 360™, Live Picture PhotoVista™, and MGI PhotoSuite III™.

[0004] Typically a digital image program is executed by a personal computer, which has sufficient processor power and memory to buffer and manipulate the series of pictures to be stitched into the panoramic picture. Typically the resulting panoramic picture is saved as a JPEG

image. The JPEG image is saved horizontally scan line by scan line and thus spans the width of the entire series of pictures. Thus, the personal computer must buffer the entire series of pictures, decide how to stitch them, and then write the resulting panoramic picture horizontally scan line by scan line.

[0005] As cellular phones and handhelds (e.g., a Palm devices) with built-in cameras become increasing popular, these devices can be expected to create panoramic pictures despite their slow processors and limited memories. Similarly, digital cameras can be expected to perform panoramic functions. Thus, what is needed is panoramic software for portable devices that efficiently utilizes their limited resources.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Fig. 1 is a flowchart of a method for creating a panoramic image in one embodiment of the invention.

[0007] Fig. 2 illustrates the creation of a panoramic image using the method of Fig. 1 in one embodiment of the invention.

[0008] Figs. 3 and 4 illustrate the projection of an image onto a cylinder for creating a panoramic image in one embodiment of the invention.

[0009] Fig. 5 illustrates a resolution pyramid used for matching two images in one embodiment of the invention.

[0010] Fig. 6 illustrates a minimum color difference path in an overlapping region between two images in one embodiment of the invention.

[0011] Fig. 7 illustrates a blending operation to smooth the transition between two images in the panoramic image in one embodiment of the invention.

[0012] Use of the same reference numbers in different figures indicates similar or identical elements.

SUMMARY

[0013] In one embodiment of the invention, a method for generating a panoramic image includes receiving a first image, dividing the first image into a first portion and a second portion, rotating the first portion of the first image, saving the rotated first portion of the first image in a nonvolatile memory, receiving a second image, dividing the second image into a third portion and a fourth portion, matching an overlapping region between the second portion of the first image and the third portion of the second image, stitching the second portion of the first image and the third portion of the second image to form a first stitched image, rotating the first stitched image, and saving the first stitched image in the nonvolatile memory.

DETAILED DESCRIPTION

Method for Creating a Panoramic Image

[0014] Fig. 1 is a flowchart of a method 10 for creating a panoramic image in one embodiment of the invention. Method 10 can be implemented with software executed by hardware on a portable device such as a camera phone, a handheld device, or a digital camera.

[0015] In step 12, the device receives or captures an image (e.g., image 1 in Fig. 2) in a series of images that makes up a panoramic image (e.g., panoramic image 8 in Fig. 2).

[0016] In step 14, the device projects the current image (e.g., image 1) onto a cylinder to generate a warped image. The warped image presents a realistic panoramic view to the user by placing the user at the center of the cylinder with the series of images projected onto the wall of the cylinder.

[0017] In step 16, the device divides the current image (e.g., image 1) into a left portion (e.g., left portion 1A in Fig. 2) and a right portion (e.g., right portion 1B in Fig. 2). The device then orthogonally rotates the left portion of the current image (e.g., left portion 1A of image 1) in a first direction (e.g., clockwise), and saves the rotated left portion as the first part of the panoramic image (e.g., panoramic image 8) in nonvolatile memory. In one embodiment, the panoramic image is saved in JPEG format so the rotated left portion is processed and saved horizontally scan line by scan line. The right portion of the current image (e.g., right portion 1B

in image 1) is not yet rotated because it will be used to determine an overlap between the current image and the next image.

[0018] In step 18, the device receives or captures the next image (e.g., image 2 in Fig. 2) in the series of images that makes up the panoramic image (e.g., panoramic image 8). In one embodiment, the viewfinder of the device displays the right portion of the previous image (e.g., right portion 1B of image 1) so the user would know what portion of the scene should be included in the next image (e.g., image 2) to form the panoramic image.

[0019] In step 20, the device projects the current image (e.g., image 2) onto the cylinder to generate another warped image.

[0020] In step 22, the device divides the current image (e.g., image 2) into a left portion (e.g., left portion 2A in Fig. 2) and a right portion (e.g., right portion 2B in Fig. 2). The device then matches the right portion of the previous image (e.g., right portion 1B of image 1) with the left portion of the current image (e.g., left portion 2A of image 2) to determine the overlap between the previous image and the current image. In one embodiment, the device only searches a sub-portion of the left portion of the current image (e.g., sub-portion 2A-1 of image 2 in Fig. 2) for a match with the right portion of the previous image (e.g., right portion 1B of image 1). Once a match is found, the device aligns and then stitches together the right portion of the previous image and the left portion of the current image to form a stitched image (e.g., stitched image 4 in Fig. 2).

[0021] In step 24, the device blends the colors from the right portion of the previous image (e.g., right portion 1B of image 1) and the left portion of the current image (e.g., left portion 2A of image 2) to provide a smooth transition from the previous image to the current image.

[0022] In step 26, the device orthogonally rotates the stitched image in the first direction and then saves the rotated stitched image as a part of the panoramic image (e.g., panoramic image 8) in nonvolatile memory. As described above, in one embodiment, the panoramic image is saved in JPEG format so the rotated stitched image is processed and saved horizontally scan line by scan line. The right portion of the current image (e.g., right portion 2B of image 2) is not yet

rotated because it will be used to determine the overlapping region between the current image (e.g., image 2) and the next image (e.g., image 3 in Fig. 2).

[0023] In step 28, the device determines if there is another image in the series of images that makes up the panoramic image. If so, step 28 is followed by step 18 and method 10 repeats until all the images in the series have been processed to form the panoramic image. If there is not another image in the series, then method 10 is followed by step 30.

[0024] In step 30, the device orthogonally rotates the panoramic image (e.g., panoramic image 8) in a second direction (counterclockwise) so the panoramic image is now in the correct orientation for viewing by the user. The device can also crop out the curvature in the panoramic image to make the final image rectangular. The device then saves the final panoramic image in nonvolatile memory.

Projecting an Image onto a Cylinder

[0025] As described above in steps 14 and 20 (Fig. 2), the device projects the images that make up the panoramic image onto a cylinder as exemplified by images I_1 and I_2 in Fig. 3. This creates a realistic panoramic view to the user as if the user is standing at the center of the scene and viewing the surrounding when the user is actually viewing the series of images projected onto the wall of the cylinder.

[0026] To project the images on the cylinder, several assumptions are made. First, the focal length of the camera is assumed to be fixed and known. For example, the focal length of the camera can be provided by the device manufacturer. Second, the camera is assumed to have no other motion other than rotation around while taking the series of images. Third, the rotational axis is assumed to be parallel to the y-axis of image. To simply the projection model shown in Fig. 3, it is assumed that the focal length of the camera is f, the radius of cylinder is f, and the distances from the rotational axis to the image planes are also f.

[0027] Referring to Fig. 4, plane I is the image plane and cylinder Cy is the cylinder where the images are to be projected. Origin O_I is located at the center of image plane I and origin O is located at the center of cylinder Cy. Point C_I lies on the x-axis of image plane I and point C is

located at the intersection of line OC_I and cylinder Cy. From trigonometry, the following correlation is inferred:

$$\frac{O_IC}{OO_I} = arctan\frac{O_IC_I}{OO_I} \tag{1}$$

[0028] Point B_I is an arbitrary point in image plane I. Point C_I is the projection of point B_I onto the x-axis on image plane I. Line B'C is the projection of line B_IC_I onto cylinder Cy and point B is the projection of point B_I onto cylinder Cy. Here $\triangle$OBC is similar to $\triangle OB_IC_I$. From trigonometry, the following correlation is inferred:

$$\frac{BC}{OC} = \frac{B_IC_I}{OC_I} = \frac{B_IC_I}{OO_I / cos\frac{O_IC}{O_IO}} \tag{2}$$

[0029] Suppose the image coordinates of point B_I is (x, y) and the cylinder coordinates of B is (x', y'), equation 2 can be rewritten as:

$$x = f\,tan\frac{x'}{f}\text{ , or } x' = f\,arctan\frac{x}{f}\text{, and} \tag{3}$$

$$y = y'\cos\frac{x'}{f}\text{, or } y' = y\sec\frac{x'}{f}. \tag{4}$$

[0030] Thus, equations 3 and 4 are used to project the images that make up the panoramic image onto cylinder Cy. From equations 3 and 4, it can be seen that the relationship between *y* and *y'* is linear if *x'* or *x* is fixed and the formula for *x'* is independent of *y*. Thus, the calculation of *x'* and *y'* has been separated to reduce the complexity of the projection computation.

[0031] For example, one vertical line having value *x* in the image plane corresponds to one projected vertical line having value *x'* on the cylinder. Thus, value *x'* only needs to be determined once for projecting one vertical line having value *x'* in the image plane. As *x'* is constant, *y'* values for each vertical line on the cylinder can be calculated simply as a function of *y* because $sec\frac{x'}{f}$ is constant in equation 4. Values of $arctan\frac{x}{f}$ and $sec\frac{x'}{f}$ can be stored in a lookup table instead of being calculated in real time to speed up the projection computation.

Matching Current and Previous Images

[0032] As described above in step 22 (Fig. 1), the device must match the current image and the previous image in order to align and stitch the images together to form a panoramic image. This can be done by placing one image over the other and determining how closely the two images match. As described above, the overlapping region to be matched and searched can be limited to a portion of the total image area, such as left portion 1B of image 1 (Fig. 2) and sub-portion 2A-1 of image 2 (Fig. 2), to speed up the matching process and to reduce the computing cost. In one embodiment, the device searches for shared features between the two images and uses these shared features to align the images. Typical features used for matching includes points, lines, and region topology. In one embodiment, the device uses a conventional RANSAC (Random Sample Consensus) algorithm to match the shared features between the two images.

[0033] To further speed up the matching process and reduce the computing cost, the device utilizes a resolution pyramid in one embodiment of the invention. The use of the resolution pyramid is described in commonly owned U.S. Patent Application Serial No. 09/665,917, entitled "Image Matching Using Resolution Pyramids with Geometric Constraints," filed September 20, 2001, which is incorporated by reference in its entirety. The use of the resolution pyramid is briefly described in reference to Fig. 5.

[0034] A resolution pyramid 50 can be constructed for each image to be matched. Resolution pyramid 50 includes n levels of the image at different resolutions, which range from the original resolution at level L_0 to the coarsest resolution at level L_t. In one embodiment, each upper level is derived from a lower level down sampled 2 by 2 pixels to 1 pixel.

[0035] At the top level, the image is small enough that matching two images can be accomplished relatively easily. For example, the device detects and matches features in the two images, or portions of the two images, at the top level to determine a camera motion. The device then uses the camera motion to guide the search at the next lower level. For example, the device first detects features in the previous image (or a portion of the previous image) at the next lower level. Instead of performing an exhaustive search of the current image (or a portion of the current image) for the shared features, the device searches areas of the current image (or a portion of the current image) where the camera motion predicts the shares features should be

located. After searching and matching the shared feature, the device determines a refined camera motion that can be used again to further match the two images.

Blending the Overlapping Region

[0036] As described above in step 24 (Fig. 1), the overlapping region between two stitched images are blended to provide a smooth transition between images. In practice, the scene being captured often changes between the time when the device receives or captures the two images. This causes the content of the overlapped region between the two images to be less than identical. For example, if a man is walking in the scene, then the position of this man is different in these two images to be blended. A conventional blending method will result in a blurry panoramic image because the color values of the man would be blended into the image.

[0037] Fig. 6 illustrates how the device prevents blurring in one embodiment of the invention. The device matches an overlapping region 84 between a right portion 81B of a previous image and a left portion of 82A-1 of the current image. To prevent blurring, the device first determines a color difference map of overlapping region 84 between the previous image and the current image. The device then determines a path 86 that has the minimum color difference in overlapping region 84. In one embodiment, a weighted color difference of a pixel is calculated as:

$$D_{ij} = d_{ij} + d_{i-2,j-1} + d_{i-1,j-1} + d_{i,j-1} + d_{i+1,j-1} + d_{i+2,j-1}, \qquad (5)$$

where D_{ij} is the weighted color difference of a pixel *(i,j)*, d_{ij} is the color difference of pixel *(i,j)* from the color difference map, and $d_{i-2,j-1}, d_{i-1,j-1}, d_{i,j-1}, d_{i+1,j-1}, \text{and } d_{i+2,j-1}$ are the color differences of the five lower neighbors of pixel *(i,j)* from the color difference map. Minimum color difference path 86 is the path that has the minimum color difference sum of all the pixels that make up the path out of all the possible paths through overlapping region 84.

[0038] The device stitches the previous image and the current image by filling the left of minimum color difference path 86 with the previous image, and filling the right of minimum color difference path 86 with the current image. If the colors of a scan line on the two sides of path 86 are similar, then the device blends the color values of the two images along a blending

width W centered on path 86. The colors of a scan line on the two sides of path 86 are similar if the color difference of the pixel on path 86 in that scan line is less than a threshold value. If the colors of a scan line on the two sides of path 86 are too different, then the device does not blend the color values of the two images. Thus, the device prevents blurring by detecting a possible change in the scene and stops the blending of the two images.

[0039] Fig. 7 illustrates how the device blends the colors of the two images on a scan line in one embodiment of the invention. As illustrated in Fig. 7, the color value of the previous (e.g., left) image on path 86 is greater than the current (e.g., right) image on path 86 for a particular scan line. Thus, color values are subtracted from the previous image along half of blending width W (i.e., W/2) while color values are added to the current image along blending width W/2 to provide a smooth transition between the two images along path 86. Conversely, if the color value of the previous image on path 86 is less than the color value of the current image on path 86 for a particular scan line, then color values are added to the previous image along blending width W/2 and color values are subtracted from the current image along blending width W/2.

[0040] First, the device determines color values that are to be added to or subtracted from the color values of the previous image and the current image along blending width W. The color value to be added or subtracted is the product of a curve 102 and the color difference d_{ij} of the pixel on path 86. Specifically, the device uses the following formula:

$$C(x) = \frac{d_{ij}}{2} \times \left(1 - \frac{x}{W/2}\right), \qquad (6)$$

where $C(x)$ is the color value to be added to or subtracted from a pixel located x away from pixel (i,j) on path 86, d_{ij} is the color difference of pixel (i,j), $\left(1 - \frac{x}{W/2}\right)$ represents curve 102, and W is the blending width.

[0041] In one embodiment, to speed up the blending operation, the device defines blending width W to be the largest integer of 2^n that is less than width W_{max} of portion 81B and 82A-1 (Fig. 6). By defining blending width W so, the device can use shift operation in equation 6 instead of integral dividing to blend the color of the two images.

[0042] Various other adaptations and combinations of features of the embodiments disclosed are within the scope of the invention. Numerous embodiments are encompassed by the following claims.